Aleppo pine (Pinus halepensis.Mill) reafforestation stem form study using natural form factors method

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Abstract: Form factors are often used for stem timber volume estimation at both tree and forest stand levels. But this estimation becomes easy and faster when for each species is established a table where are ordered these factors according to the trees height. This contribution proposes such table for Aleppo pine reforestation realized in 1890 in the region of Tlemcen (West of Algeria). The method used for its establishment uses advantageously the existing relation between natural and artificial (breast-height) factors and requires a limited number sample trees (50 to 80 only). The obtained values, from 0540 to 0356 for respectively 6 to 25 meters heights, express better taper of the stems in the study stand and allow practically quick stem timber volume evaluation in our survey zone or in other similar stations.

Key-words: Aleppo pine, form factor, relative height, stems volume

1. Introduction

Two main methods are used in forest practice for stem timber volume estimation: Direct evaluation through taper measurement and indirectly through volume tables (or equations). Although it's expensive, direct taper measurement is the most accurate as it takes into account the real stem form: For a long time, it's admitted that for a given diameter and height, stem timber volume is absolutely linked to its form [1]. Various dendrometrical expressions were established to embody the stem general form but the currently used one is the form factor [2].

The form factor is the ratio of the stem volume to a fixed diameter or length and the volume of a cylinder witch basis is the basal area (g) of a section at a fixed height and which height is the reference hr of the considered volume: fi = v/gihr (1). When the level "i" corresponds to a man height (1.30 m), we specify the breast height or the artificial form factor whose great inconvenient is its dependence on height. Other mathematical expressions characterize stem form through relationships between diameters measured at two different levels [3]. Their general form is [1]: d/dhp = f(h/H) (2) where (d) is the stem diameter measured at the height (h), (bhd) the breast height diameter and (H) the total tree height.

In forest practice are known others form factors that the ones measured to breast height. In 1880, Smallians and Pressler proposed the natural form factors [4]: initially, the natural factor is defined by the ratio of a given stem volume and the volume of a cylinder having as basis the basal area to 1/20 of the stem height, and as height, the stem height. Later, this notion is extended by measuring basal areas in any relative heights (1/n). It's expressed therefore by the formula: $fn = v/g_1/nh$ (3). The particular case of the natural factor is the absolute one that relates to a basal area measured to the stem basis, so to a relative height $1/\infty = 0$ from where $f_0 = v/g_0h$ (4).

The three form factors types ($f_{1.3}$; f_n ; f_0) are very important for both stem and stand timber estimation. Indeed, equations based on basal area, dominant (or mean) height and an evaluation of (f) permit quick volume calculation of forest stands. But the form factors are hardly appreciated or measured accurately for an inexperienced observer [2). Although it's possible to estimate them from yield tables or by using the relascope of Bitterlicht, they can be presented in special tables whose construction can be achieved through four methods: the statistical method, the taper method at breast height, the form quotient method and the method of the natural form factor to relative height (0.x). The common inconvenience to the first three methods is the necessity to cut an important number sample trees (some thousands for the statistical method for example).

The natural factors method while using the existing relation between artificial factor at breast height and those naturals, permits to avoid the disadvantages of the former methods. Indeed, the natural factor is fully independent of the tree height and is the real expression of its form. Besides, the method doesn't require a great number samples trees and the felling can be limited to only 60 or 80 trees. Another advantage of the method is that the obtained natural factors are considered in the practice as artificial. The Aleppo pine (dominant resinous specie in Algeria) form factors table establishment will have a double interest therefore: to know better form factors values of Aleppo pine reforestation and to allow the foresters to overcome constraints often linked to stand timber volume estimation because of volume or yield tables unavailability.

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2. Materials and methods

2.1. Study area

The suburban state forest of Tlemcen (figure1) is a pure Aleppo pine (*Pinus Halepensis.Mill*) reforestation dating from 1890. It is localised upstream of Tlemcen city, to an average altitude of 1023 m. The undergrowth is characterized by the presence of Juniper (*Juniperus oxycedrus*), of asparagus (*Asparagus acutifolius*), of doum (*Ampelodesma mauritanica*),of holm-oak (*Quercus ilex*), of spiny broom (*Calycotome spinosa)* and of the dwarf palm (*Chamaerops humilis*). The forest was integrated in 1993 to the national park of Tlemcen, and spreads on 286 hectares. Generally, it presents a topographic homogeneity with the exception of the north part, where the slope is of 25% and more. The forest growths on the chalky substratum under the influence of Mediterranean climate with two well distinct seasons: a cold and humid short term wintry season, and a hot and dry long term summery season [5].

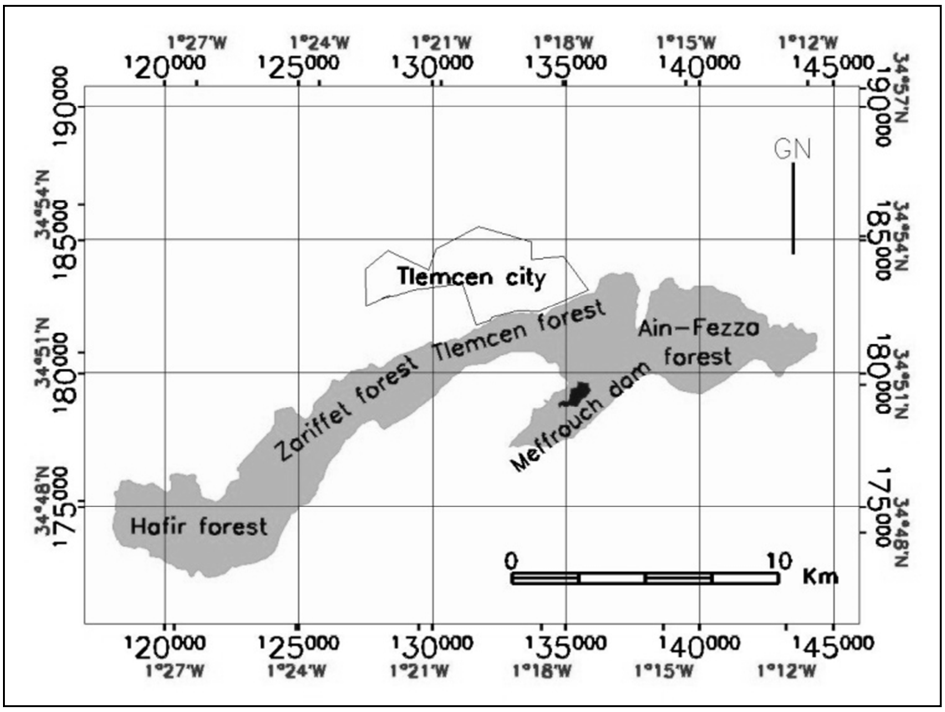

Figure 1: Study area localisation (North Algeria Lambert kilometric projection)

2.2. Principle of the method

The method combines both artificial and natural factors advantages: the factors are calculated as naturals but in practice are used as artificial. Such decision is based on the existing relationship between the two factors types. Indeed and for a set natural factors, there is certainly one that is at the same time artificial and natural: it’s the factor corresponding to the relative height 1.3/h. Figure 2 shows that for a given stem are calculated several natural form factors. The stem is divided in five sections and as basis of calculation is used the basal areas (diameters) measured to 1/10 (0.1), 3/10 (0.3), 5/10 (0.5), 7/10 (0.7) and 9/10 (0.9) of the height. Notice that higher is measured the diameter, smaller will be the volume of the cylinder to compare to the stem volume, fact that leads to great values of its correspondent natural factors.

Graphically, these natural factors are expressed by the natural form factors curve (figure 3) from where we can determine breast-height form factors (($f_{1.3}$). In fact, this last is a natural factor at relative height 1.3/h. To establish form factors table using this method, four stages are necessary:

To select and to treat a sufficient number of sample trees
To calculate for every sample tree a serial of natural factors
To calculate the mean arithmetic curve of the natural factors
To construct the natural form factors table

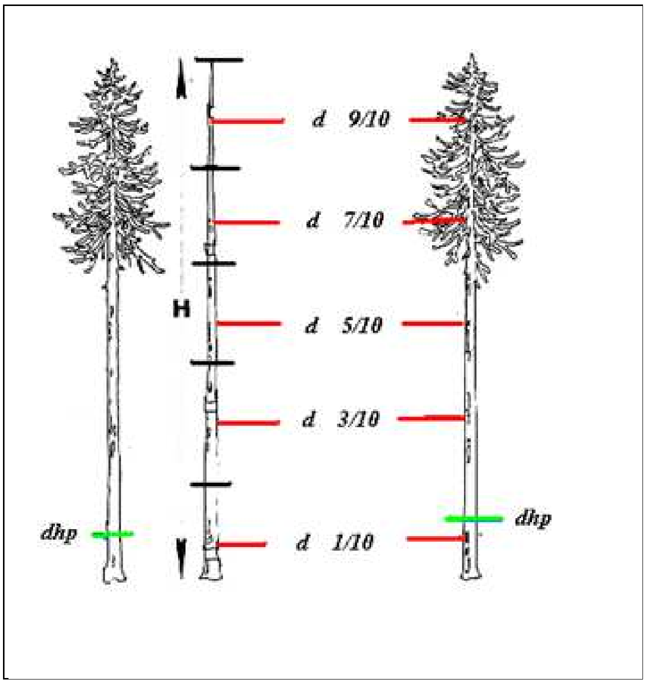

Figure 2: Stem Segmentation scheme of equal length sections

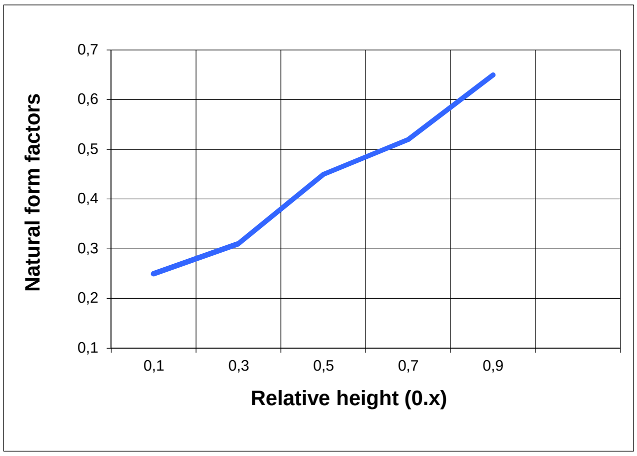

Figure 3: Natural form factors curve general appearance

Generally, the method requires felling and measuring of about sixty samples trees of a height superior to 20 meters. The measures on the sample trees are the same that those serving to stem timber estimation using the commercial formula of Huber applied to successive sections. The profile of every sample tree is plotted then in a coordinates system, in ordinates the diameters and in abscissas the heights to which are measured these diameters. For every sample tree processed in this way are calculated a set of natural form factors. This last serves to calculate graphically the mean curve from where will be read directly the natural factors at relative height (1.3/h) and corresponding to different values of the height.

2.3. Field measures

The field data concern the description of both forest stand and dendrometrical characteristics of the sample trees.

2.3.1. Forest stand description

The description of some qualitative variables permits to get a characterization of the site making possible its comparison with other sites. Indeed, the fundamental problem of the stem volume estimation affects the relation between the tree form and the site conditions [6]. Generally, the description must be about the composition, the cover, the physical difficulties of exploitation and the relative importance of the regeneration of the different species. This description is completed by an ecological report permitting to determine the evolution series of the forest stand [7]. In our case, five variables were described: the exposition and the slope (with a clinometer-compass), the altitude (with an altimeter), the soil and finally the recovery of the arborescent stratum. The table I summarise the survey zone characteristics by sample plot.

Table 1: Physical Sample-plots characteristics

Sample-plots	Exposition	Altitude (m)	Slope(degree)	Soil depth (cm)	Recovery (%)
1	North	1050	12°	10	40 %
2	North-west	950	8°	15	55 %
3	north-east	1120	20°	8	45 %
4	North	1010	14°	12	50 %
5	North	1100	9°	10	60 %

2.3.2. Dendrometrical characteristics measure

Two main dendrometrical parameters are necessary for our survey, the diameter and the height. The trees felling being impossible, we used the relascope of Bitterlich since this instrument permits to measure the diameters in different heights. Within each of the 5 plots, 10 sample trees have been selected, i.e. 50 trees to the total. The selection criteria are the stem rectitude, the height and the sanitary state. Two techniques are possible for taking measures: to divide the stem in several successive sections of equal length (2m for example) and in this case the diameter in the middle of the first will be measured to 1 m of height, the one of the second to 3 m and so forth, or to divide the stem in a defined sections number (i.e. 10 in our case) but of variable length according to the full height of the tree.

3. Results and discussion

For a given sample tree is calculated a set of natural factors using the formula $f_n=g_n/g_{0,x}$ (5) where g_n is the tree natural basal area : It is the arithmetic mean of the basal areas measured in the middle of every section. Since the trees have been divided in 10 sections (i.e. 20 half - sections), the middle of the first section will be to 1/20 the tree height, the one of the second to 3/20, of the third to 5/20, of the fourth to 7/20 etc. In other words, we obtain the relative heights 0.05; 0.150; 0.250; 0.350 etc. But It's necessary to take always into account the relative height 0.x = 0.100. Having calculated gn and g0.x, we can determine easily for a given sample tree, the natural form factors by the formula (5). The table 2 shows an example among the 50 treated trees in this survey.

Table 2: Example of calculation of the natural form factors of the sample tree n°2

$H_{l/2}$ (m)	$D_{l/2}$ (m)	$G_{l/2}$ (m^2)	0,x	$D_{0,x}$ (m)	$G_{0,x}$ (m^2)	$F_n = G_n/G_{0,x}$
1.11	0.772	0,468	0.05	0.772	0,468	0.341
			0.100	0.728	0.416	0.384
3.33	0.685	0.368	0.150	0.685	0.368	0.434
5.55	0.583	0.267	0.250	0.583	0.267	0.599
7.78	0.495	0.192	0.350	0.495	0.192	0.833
10.01	0.416	0.136	0.450	0.416	0.136	1.17
12.23	0.337	0.089	0.550	0.337	0.089	1.79
14.46	0.248	0.048	0.650	0.248	0.048	3.33
16.68	0.155	0.019	0.750	0.155	0.019	8.42
18.91	0.095	0.007	0.850	0.095	0.007	22.85
21.13	0.061	0.003	0.950	0.061	0.003	53.33
		Σ/10 = 0.16			Σ/10 = 0.16	

Of the same way are calculated the form factors for the 49 other sample trees while establishing for each of them a similar table to the previous one (Table II). The next stage consists in constructing the table III where are given, for the 50 sample trees, the factors corresponding to the relative heights only from 0.05 to 0.250 since those relating to important relative heights are not necessary. The factors are added then by relative height and divided by the number of trees (i.e. 50) and in this way is obtained a mean set of natural form factors.

Table 3: Natural form factors values of the different sample trees

N° of the sample tree	Relative height 0,x				N° of the sample tree	Relative height 0,x			
	0,050	0,100	0,150	0,250		0,050	0,100	0,150	0,250
1	0,266	0.322	0,491	0,686	26	0,318	0.375	0,416	0,583
2	0,341	0,384	0,434	0,599	27	0,394	0.447	0,493	0,581
3	0,419	0.485	0,509	0,632	28	0,355	0.537	0,453	0,607
4	0,354	0.411	0,477	0,633	29	0,388	0.445	0,490	0,608
5	0,419	0.452	0,482	0,581	30	0,400	0.440	0,492	0,617
6	0,375	0.447	0,489	0,609	31	0,372	0.429	0,461	0,637
7	0,432	0.477	0,505	0,631	32	0,394	0.477	0,486	0,602
8	0,288	0.318	0,366	0.500	33	0,329	0.405	0,451	0,625
9	0,357	0.402	0,452	0,590	34	0,412	0.466	0,535	0,616
10	0,421	0.396	0,593	0,749	35	0,328	0.378	0,415	0,628
11	0,331	0.388	0,453	0,623	36	0,385	0.427	0,495	0,615
12	0,416	0.478	0,558	0,689	37	0,400	0.447	0,491	0,600
13	0,333	0.375	0,418	0,569	38	0,398	0.425	0,472	0,599
14	0,312	0.364	0,427	0,586	39	0,355	0.400	0,453	0,553
15	0,400	0.492	0,490	0,631	40	0,388	0.446	0,495	0,602
16	0,380	0.446	0,481	0,643	41	0,424	0.480	0,515	0,601
17	0,300	0.352	0,406	0,604	42	0,383	0.420	0,467	0,576
18	0,372	0.427	0,468	0,611	43	0,358	0.400	0,436	0,584
19	0,386	0.440	0,475	0,635	44	0,353	0.387	0,431	0,541
20	0,352	0.402	0,450	0,601	45	0,334	0.403	0,460	0,575
21	0,304	0.352	0,401	0,572	46	0,329	0.379	0,455	0,580
22	0,347	0.418	0,472	0,613	47	0,393	0.436	0,472	0,660
23	0,329	0.398	0,443	0,585	48	0,322	0.374	0,425	0,604
24	0,342	0.394	0,451	0,566	49	0,319	0.353	0,402	0,531
25	0,369	0.420	0,483	0,610	50	0,334	0.387	0,434	0,610
∑ Fn						18.11	20.803	23.275	30.279
Fn/50						0,362	0,416	0,465	0,605

Graphically, this set is illustrated by the figure 4 representing the mean curve of Aleppo pine form factors and permitting to construct the corresponding table. But it is necessary to know first this interval of the heights values of the trees to measure through this table. Then, the absolute height at breast height (1.3 m) is converted in relative height while dividing it by the height of the tree. From the form factor curve (figure 4) are read and ordered in a table (Table 4) the natural factors for relative heights 1.3/h. These last will be used as if they were measured to breast-height (i.e. 1.3m).

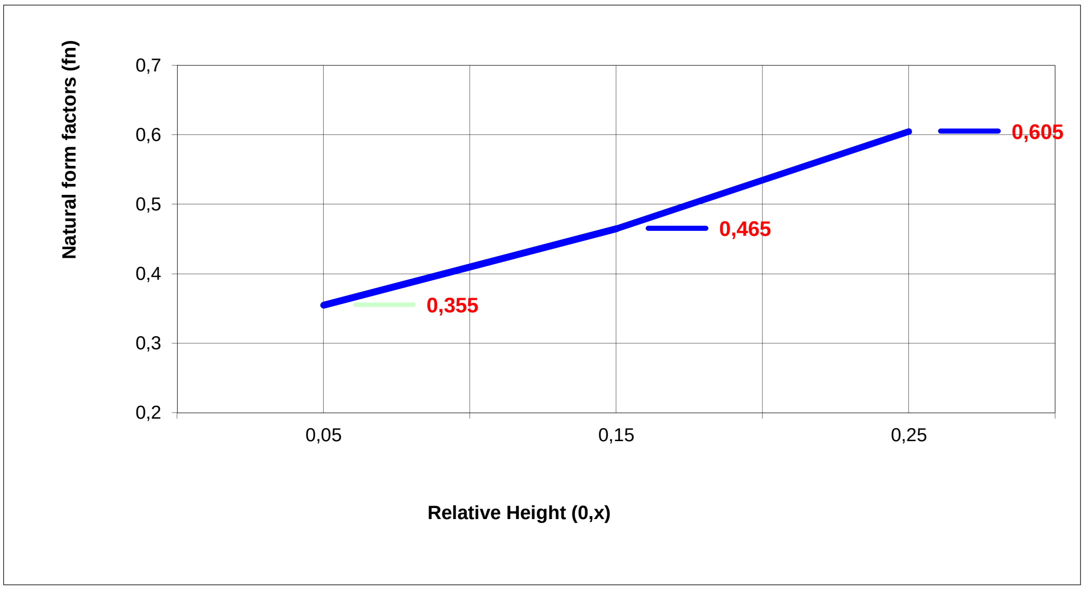

Figure 4: Mean curve of the natural form factors for the 50 sample trees

Table 4: Aleppo pine natural form factors table. Region of Tlemcen, Algeria

H	1.3/H	Fn	H	1.3/H	Fn
6	0,21	0.540	16	0,081	0,392
7	0,18	0.520	17	0,076	0,390
8	0,16	0.470	18	0,072	0,385
9	0,14	0.460	19	0,068	0,380
10	0,13	0.440	20	0,065	0,375
11	0,12	0,420	21	0,061	0,370
12	0,11	0,418	22	0,059	0,365
13	0,10	0.416	23	0,056	0,360
14	0,09	0,410	24	0,054	0,358
15	0,086	0,396	25	0,052	0,356

The obtained values give us a first idea on the possible form factors values of an Aleppo pine reforestation according to its height. These values don't move away a lot of those obtained in other regions and seems very better. By way of comparison, the table 5 gives the values obtained for the natural Aleppo pine in the “Aures” region (Eastern Algeria) according to the dominant height.

Tableau 5: Aleppo pine Form factors values. Region of Aures, Eastern Algeria [8]

Dominant height (m)	8	10	12	14	16	18	20
F	0.475	0.457	0.432	0.404	0.370	0.339	0.304

This better stem form of the study site is due to some site conditions (sub-humid climate) and probably to the genetic qualities (seeds provenance) that were in favour of this form. Globally, the obtained values are interesting and express satisfactory form and taper of specie well known by its twisted trunk, justifying therefore Aleppo pine production reafforestation.

As regard to the accuracy of this table, three error types are to fear: errors related to the instrument reading, errors related to the operator, and errors related to the used instrument. These errors could be accentuated by the site conditions: rocky and hilly terrain or sylvicultural conditions: bad lopping that doesn't permit a comfortable use of the relascope. At present and in the absence of reference data, the three mentioned errors cannot be determined.

4. Conclusion

The established form factors table will certainly be of a great utility for forest planning inventories of Aleppo pine forests in the region and particularly those resulting from reaforestation. The time and the efforts provided for its construction will be saved by the foresters for stem timber volume estimation. On other side, as it don’t requires the felling of a big number sample trees, the method of the natural form factors can be used for other species (resinous or deciduous). The resulting tables will serve subsequently to volume table’s construction. However, and in order to improve the stem volume estimation, it is recommended to acquire more knowledge on the relationships of the specie stem form with the site conditions.

References

[1] CH. Ung, Forme des tiges d'érable à sucre et de hêtre à grandes feuilles dans une jeune futaie selon leur position sociale et leur âge. Ann.Sci.For. 46(3) (1989). 261-271.

[2] J. Pardé, J. Bouchon, Dendrométrie. 2e édition. Ecole nationale du génie rural, des eaux et forêts. France. (1988)

[3] O. M'hirit, JG. Postaire., Analyse de la forme des tiges pour la construction de tarifs de cubage. Application au cèdre du Maroc (Cedrus atlantica. Manetti). Ann.sc.for.41(3). (1984). 303-322.

[4] J. Doukhovnikov, I. Mikhov, Dendrométrie. Ed.zemisdat, Sofia, Bulgarie. (1983)

[5] M. Bouazza, Etude phyto-écologique de la steppe à stipa tenacissima au sud de Sebdou - Oranie- Algérie).Thèse en sciences, Fac.Sc. Marseille- Saint - Jérôme, France. (1991)

[6] CH. Ung, Inventaire par échantillonnage pour estimer la production ligneuse et son accroissement. Partie 3. Acquisition et traitement des informations. Cours n°25, Formation continue. Ed. Ordre des ingénieurs forestiers du Québec. (2006).

[7] Saucier JP., Croissance et rendement en fonction des types écologiques photointerprétés dans la région écologique 5a-Basses et Moyennes Appalaches (Québec). Thèse de maîtrise. Faculté de foresterie et de géomatique, Université Laval. (1992).

[8] Bentouati A., Croissance, productivité et aménagement des forêts de pin d'Alep. M) du massif de Ouled Yagoub (Khenchela-Aures). Thèse de doctorat d'état en Sci..Agron. Université El Hadj Lakhdar, Batna, Algérie. (2006).